Sandia Water Initiative Overview

www.sandia.gov/water

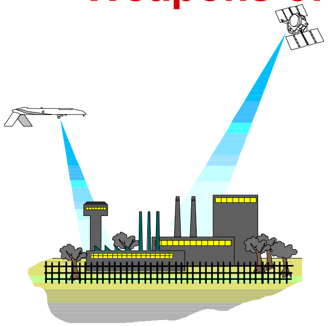
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia National Laboratories has four primary mission areas

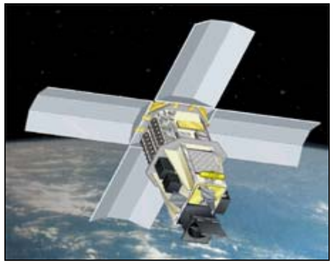
Safety, Security, & Reliability Of Nuclear Weapons


Safe, Secure, Reliable Weapons

Reduction of Vulnerability to Weapons of Mass Destruction



Detection



Surveillance

Safety, Security, & Reliability of Critical Infrastructures

Energy

Transportation

Environment

Water

Information

Enhancing National Security Measures

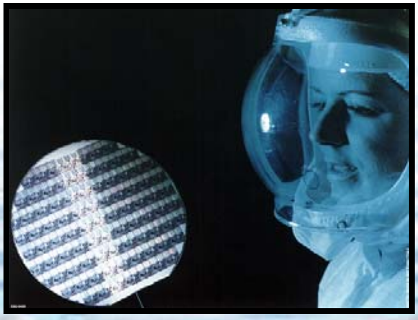
Architectural Surety

Bomb Disablement

Sandia Science and Technology is represented in 10 Councils

Sandia – in Round Numbers (as of February 2002)

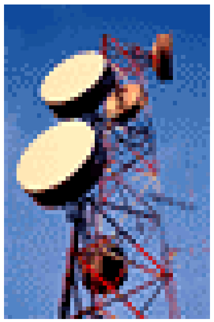
- 7,700 full-time employees
  - ~6,800 in New Mexico
  - ~900 in California
- 600 buildings, 5M square feet
- 1,450 Ph.D.'s, 2,100 Masters
  - 54% engineering
  - 29% science and mathematics
  - 17% computing and other
- Annual budget $1,700M



Sandia National Laboratories

Sandia assesses the safety, security and reliability of individual infrastructures and interdependencies among multiple infrastructures

Oil & Gas

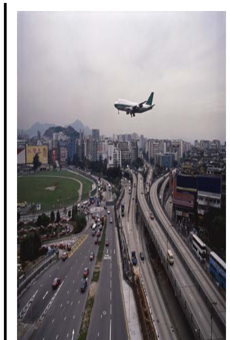


Communications

Water

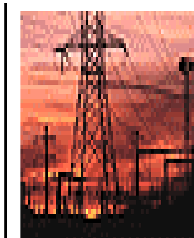
Banking & Finance

Continuity of Gov. Services



Transportation

Emergency Services



Electric Power

Interdependencies among infrastructures are a major vulnerability

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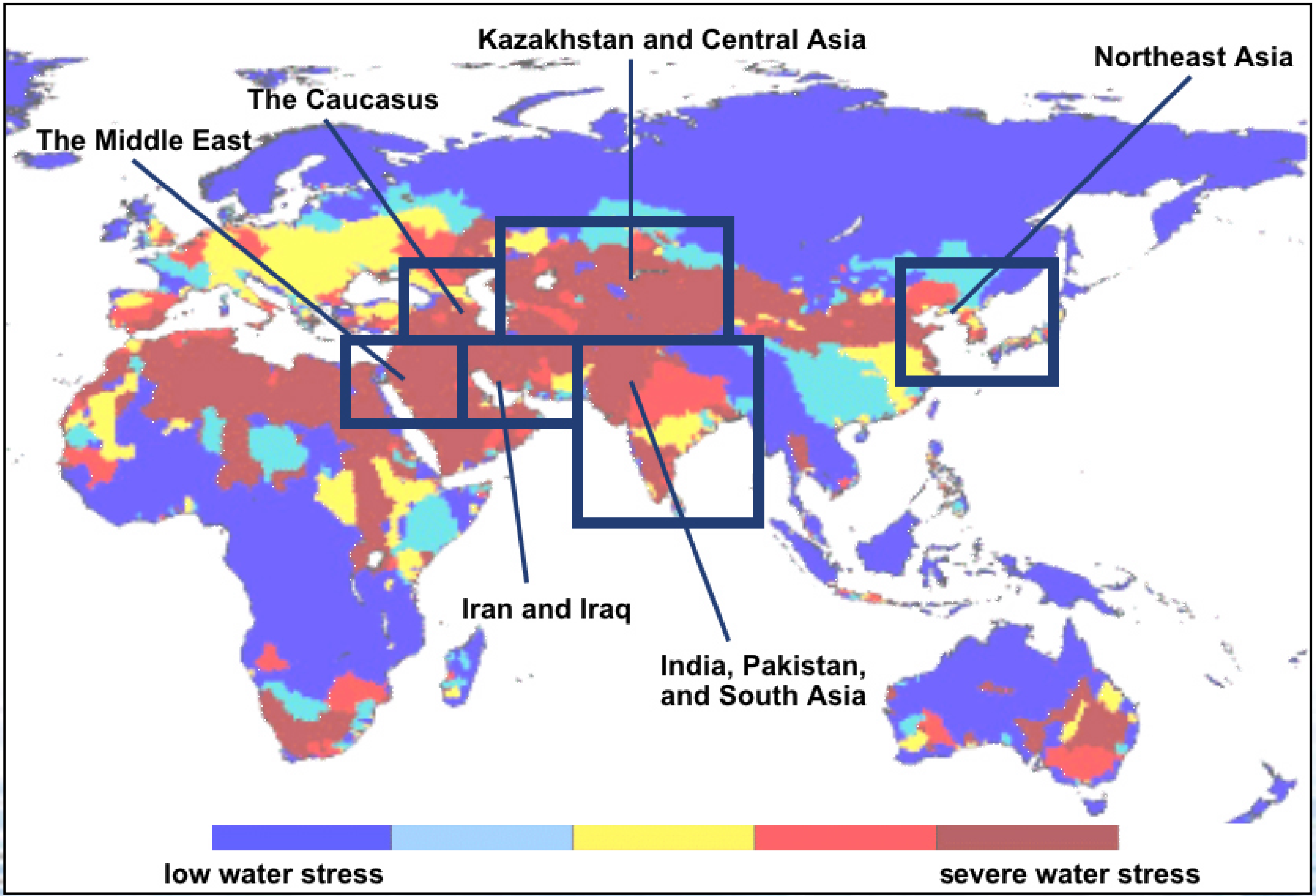
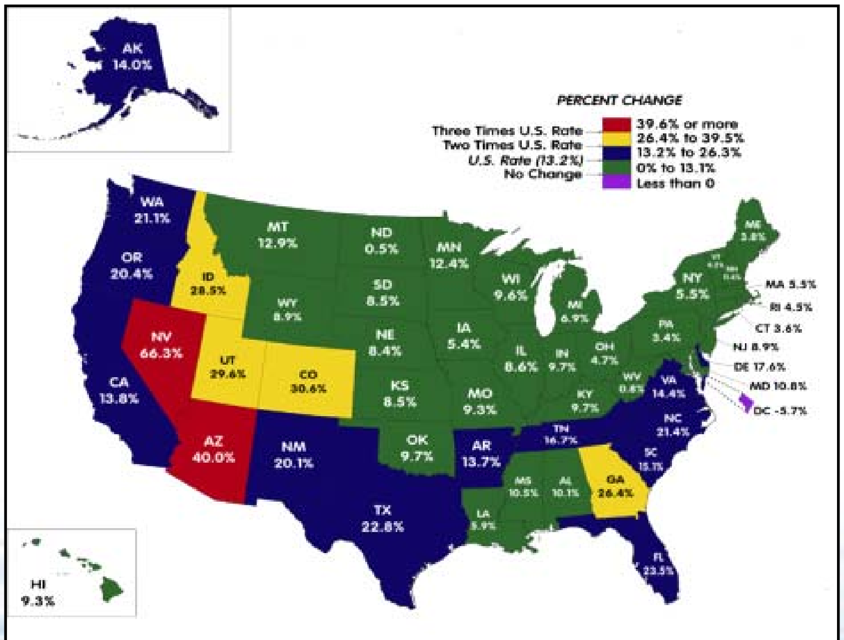
Severe water-related stress is a significant issue in every region where proliferation of weapons of mass destruction is a major U.S. concern

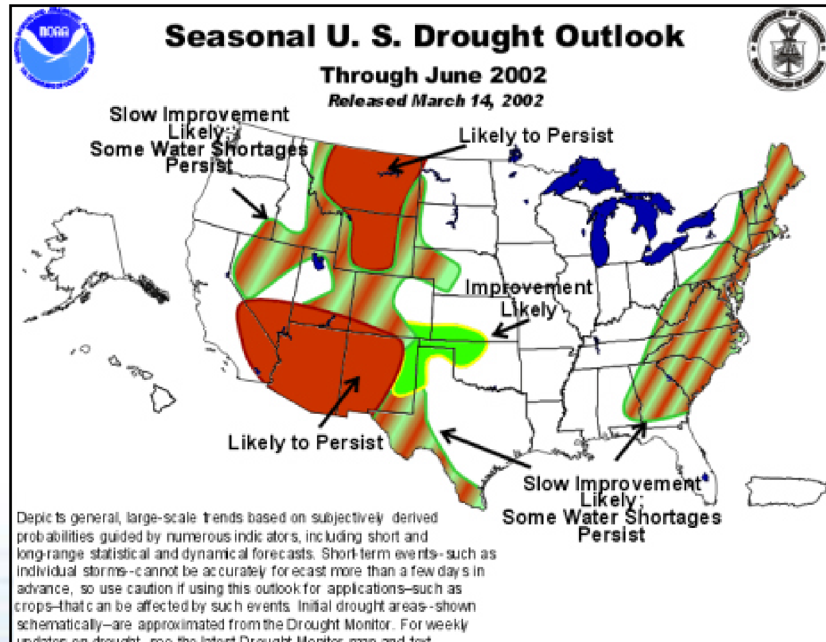


Climate change, drought, and population growth have produced unsustainable water use and elevated water conflict in the United States

Population projections indicate major growth in multiple states with growing water shortages.



Recent studies indicate that "drought" experienced in some regions are closer to "normal" climatic conditions.



Water shortages along the US-Mexico border have created a major stress in US-Mexico relations and these shortages are expected to become more severe

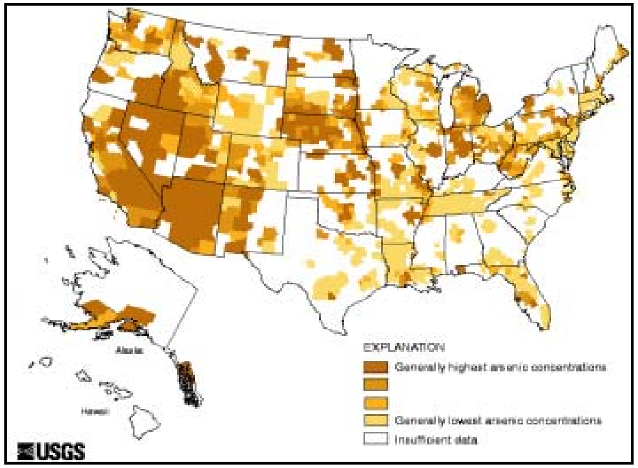
- **Ciudad Juarez and El Paso pump from the same aquifer.**

  Hydrologic studies project that Ciudad Juarez will begin running out of fresh water in 5 years and El Paso in 25-30 years.

- **Mexico's under delivery of ~1.5 million acre-feet under the US – Mexico Water Treaty of 1944 has created an issue at the Bush-Fox level.**

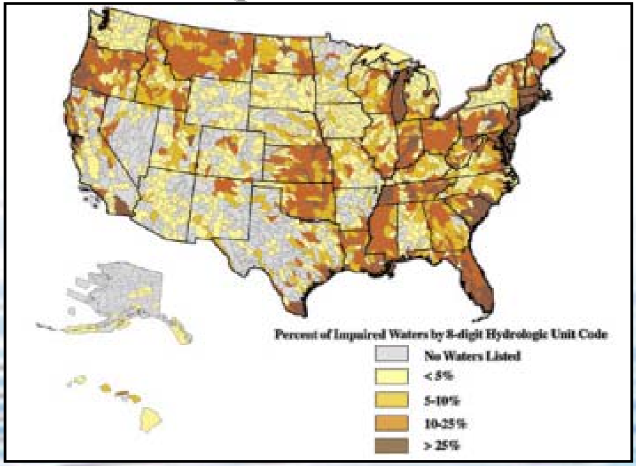
Stricter water quality standards and deteriorating water quality are driving major increases in water treatment costs

Arsenic in the United States

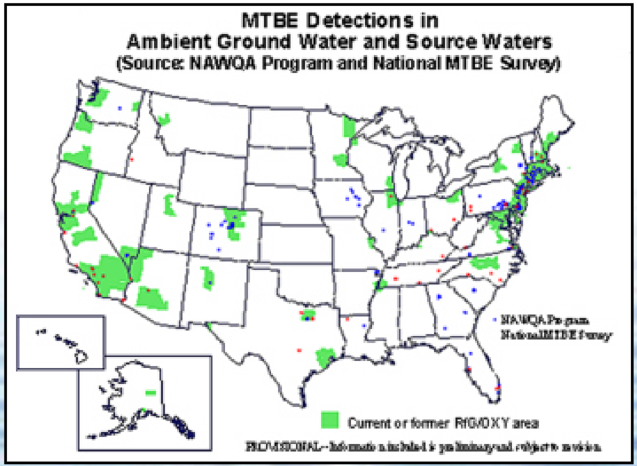


- **Annualized estimated costs for meeting 10ppb arsenic standard range from $195M/yr (EPA) to $675M/yr (AwwaRF)**
- ***What's Next?***
- **"More Waters Test Positive for Drugs"**

TMDL "impaired" water in US



MtBE contamination in US



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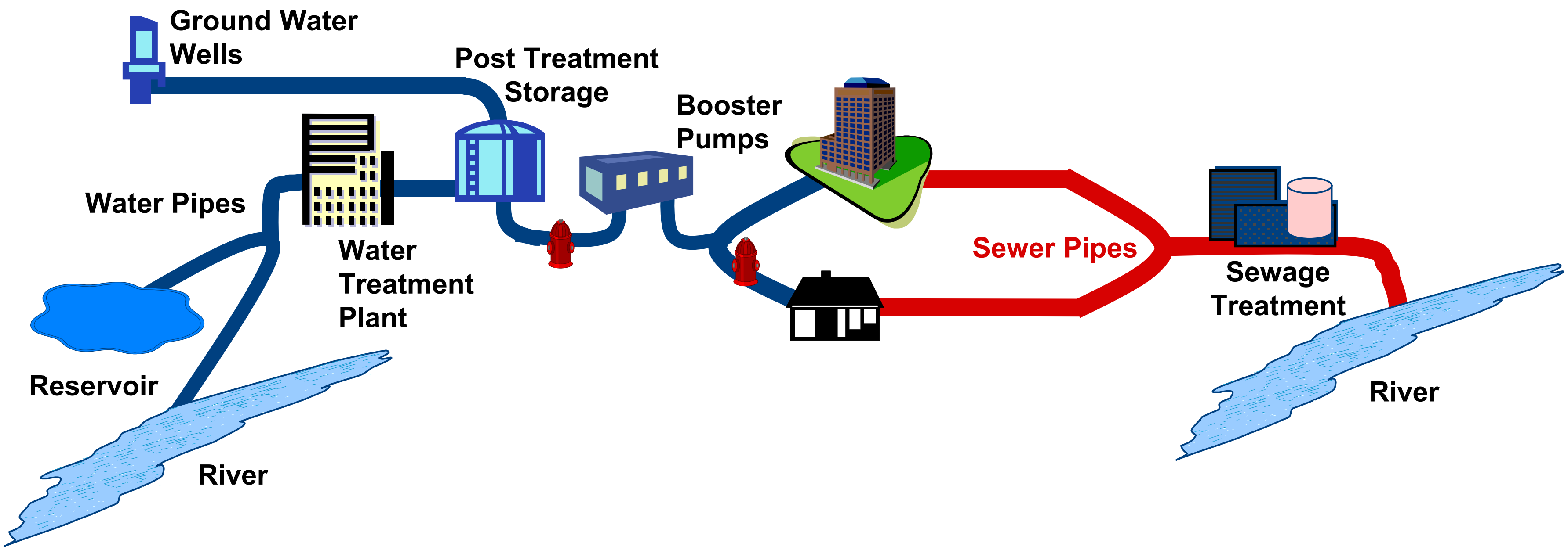
U.S. water infrastructure faces large uncertainties in the character of threats and nature of system vulnerabilities

Source → Treatment → Distribution → Sewer/Treatment → Discharge

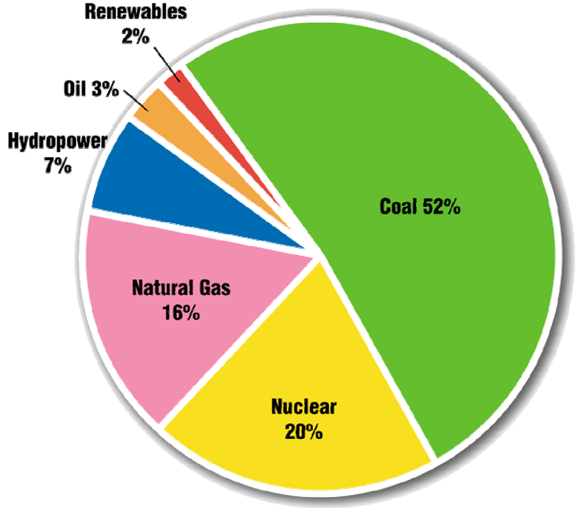


- **Potential for intentional contamination: at source, in treatment, in distribution system, and in massive amounts by wastewater release**
- **Distribution system (post-treatment) presents the greatest challenges through numerous and dispersed access points**

Energy and water are highly interdependent infrastructure elements, yet they are currently are managed independently

- Thermoelectric power production requires 190 billion gallons/day, accounting for 45% of all freshwater withdrawals (with 75% return rate)
- Energy industry is second largest consumer of water (after agriculture)
- Utility industry faces as much as $70 B in additional water-related costs
- The entire energy cycle–fuel extraction, refining, conversion, and waste disposal–impacts water quantity and quality
- Energy consumed worldwide for delivering water is 7% of total world energy consumption (equal to the total amount of energy consumed by Japan and Taiwan combined)

Electricity generation by fuel source



Each kWh from coal requires 3.3 gallons of water. This means that each person in the US indirectly uses 36,300 gallons of water yearly for electricity use, roughly equal to that consumed by all other domestic uses combined.

“Water is essential for life.”

- **Sandia is solving technological challenges innate to water safety, security, and sustainability.**
  - **Growing water shortage at global and US scales**
  - **Transboundary water management issues**
  - **Deteriorating water quality**
  - **Water infrastructure vulnerability**
  - **Energy and water interdependencies**

“Water promises to be to the 21st century what oil was to the 20th century: the precious commodity that determines the wealth of nations”

Fortune Magazine, May 2000

“The next World War will be over water”

Ismail Serageldin, Vice-President of the World Bank, From Every Drop for Sale by J. Rothfeder, 2001

Sandia Water Initiative

Security

"protecting water sources and water distribution systems"

Safety

"assuring the water we drink is free of contaminants"

Sustainability

"supplying sufficient water now and in the future"

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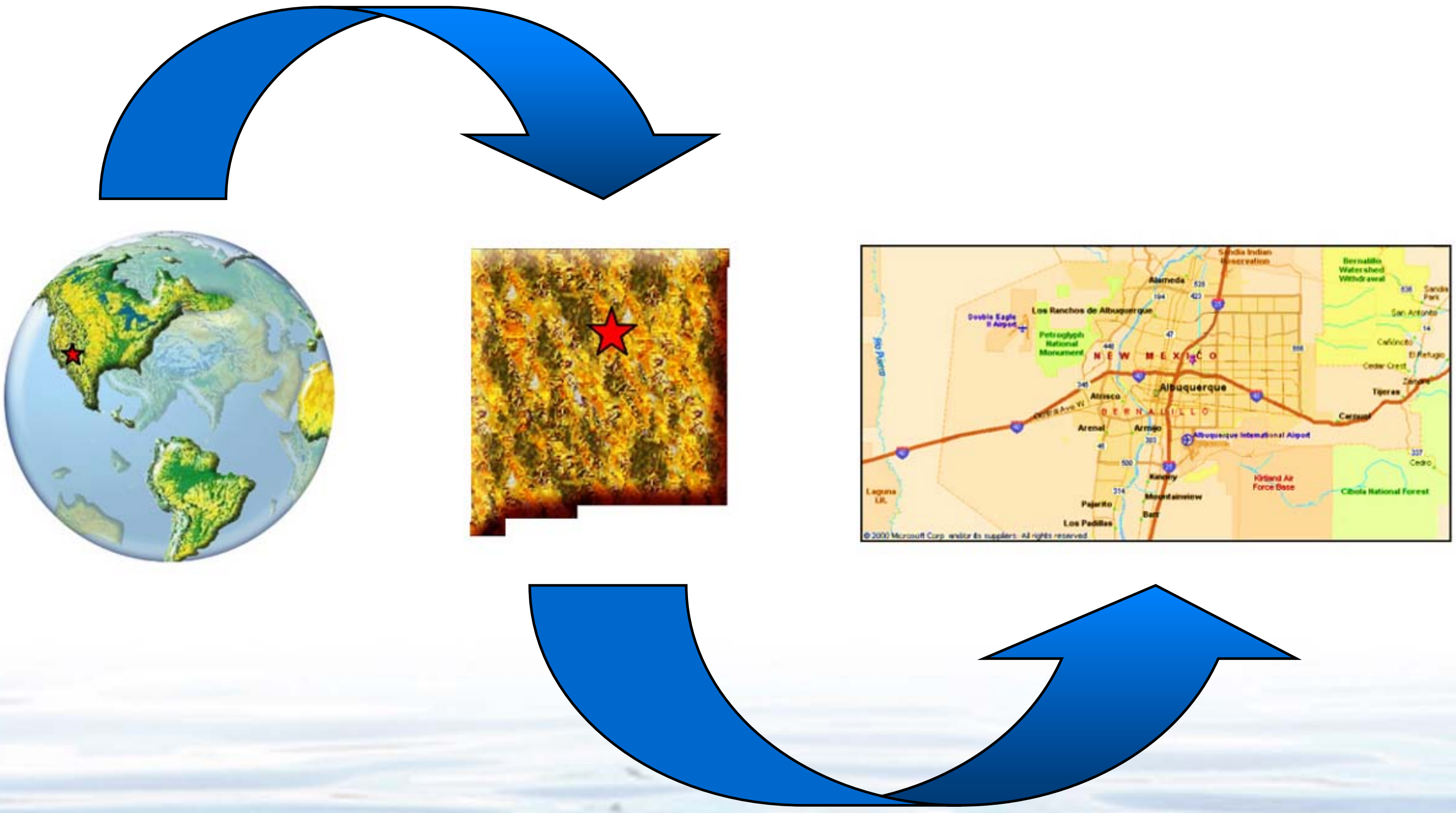
Water issues exist at all levels: from Global, to New Mexico, to Albuquerque



Significant progress has been made building external relationships and partnerships

Universities
University of New Mexico
New Mexico State University
New Mexico Tech
University of Arizona
(NFS/SAHRA)

Congress
New Mexico Delegation
Energy and Water
Energy and Natural Resources
Environment and Public Works
Transportation & Infrastructure
Science

Water Associations
Assoc. Met. Water Agencies (AMWA)
AWWA Research Foundation
American Society of Civil Engineers

Water Sector
Public Utilities
Water Engineering
Sensor/Monitoring Technologies
Water Treatment Technologies

Other Organizations
Los Alamos National Lab
National Energy Technology Lab
New Mexico Water Groups

…however,
More partnership work
Is needed…

Federal Agencies
Environmental Protection Agency
Bureau of Reclamation (DOI)
US Geological Survey (DOI)
Department of Energy
Dept. of State (IBWC, IJC)
Homeland Security (TBD)

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Technical work in 5 focus areas maps to the core themes of Safety, Security, and Sustainability

Research & Technology Areas:	Safety	Security	Sustainability
Treatment Technology	Arsenic, MtBE, et al.	Exploratory Analysis	Desalination
Infrastructure Risk	Dual-Use Ties with Security	Infrastructure Risk Assessment Methodology & Threat Analysis	Infrastructure Redesign & Design Standards
Real-Time Monitoring	Sensors for Regulated Contaminants	Sensors for Chem-Bio Contaminants	Int'l Cooperative Monitoring Projects & Low Flow Sensors
Decision Modeling	Distribution System Contaminant Modeling	Distribution System Contaminant Modeling	Multi-Stakeholder Decision Modeling
Interdependency Analysis		Critical Mission Interdependencies (component of Risk Assessment, e.g. Fire)	Energy-Water

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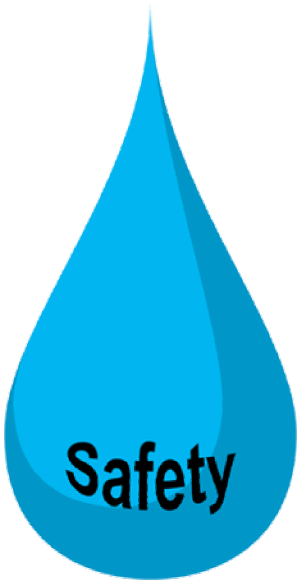
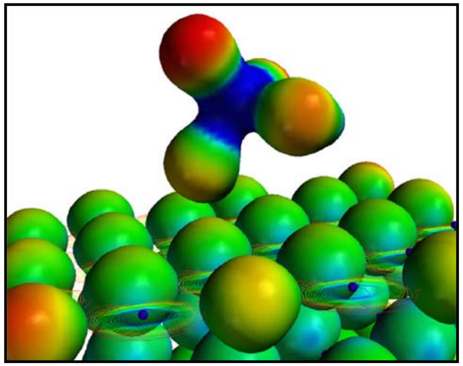
Water Treatment Technology:
Safety

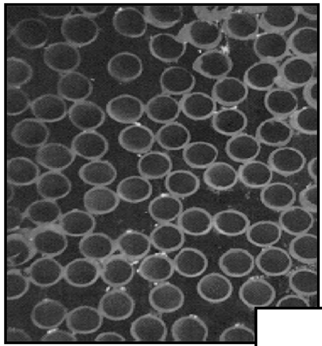


Advances in water treatment technology will have significant impact on safety, security, and sustainability



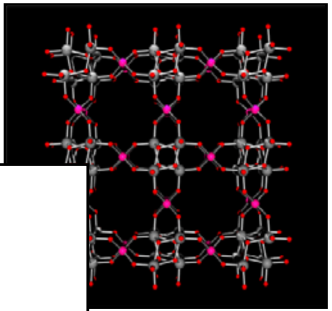
***Safety*:**
Cost-effective contaminant removal technologies

Design of arsenic-specific chemical filter materials using molecular simulation

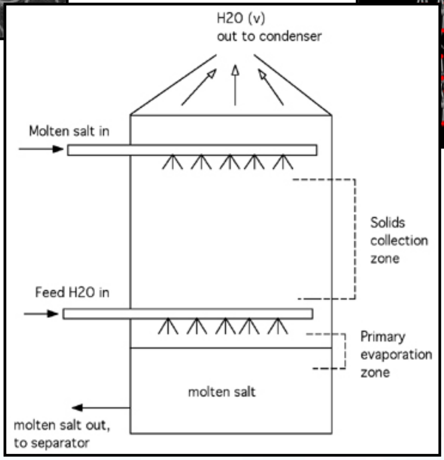


Pervaporation

***Sustainability*:**
Next-generation desalination technologies



In situ crystallization



Direct contact distillation

Integrated chem/bio treatment technologies

***Security*:**
Future treatment strategies for reducing vulnerability of water infrastructure

Point of use
(rather than centralized)
treatment technologies

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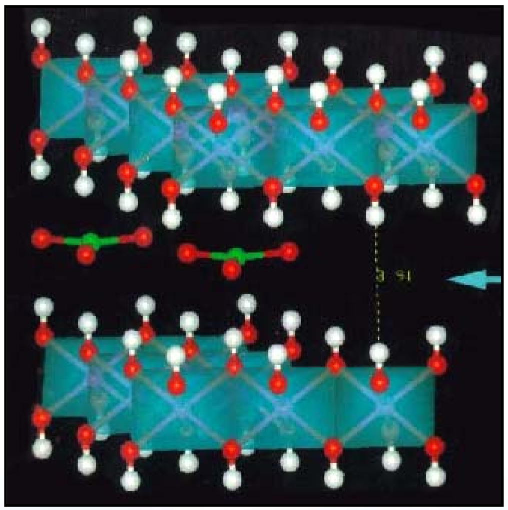
Sandia arsenic treatment research draws on molecular simulation and experience from environmental clean-up and repository design

Granular Filter Media

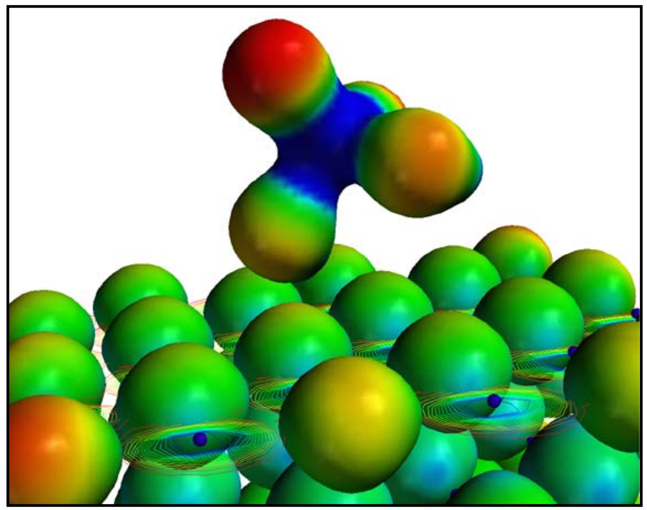
Solid-Liquid Separations

Mesoporous Sorbents



Hydrotalcite (LDH)
$M_x^{2+}M_y^{3+}(OH)_{2x+3y-nz}(A^{n-})_z \cdot mH_2O$

Specific Anion Nanoengineered Sorbents (SANS)



Mixed metal oxides selectively trap arsenic with high efficiency

Rapid Reaction Magnesium Oxide Treatment

Separation of $Mg(OH)_2$ from water after arsenic sorption

Goal: Develop technology that reduces overall arsenic treatment costs

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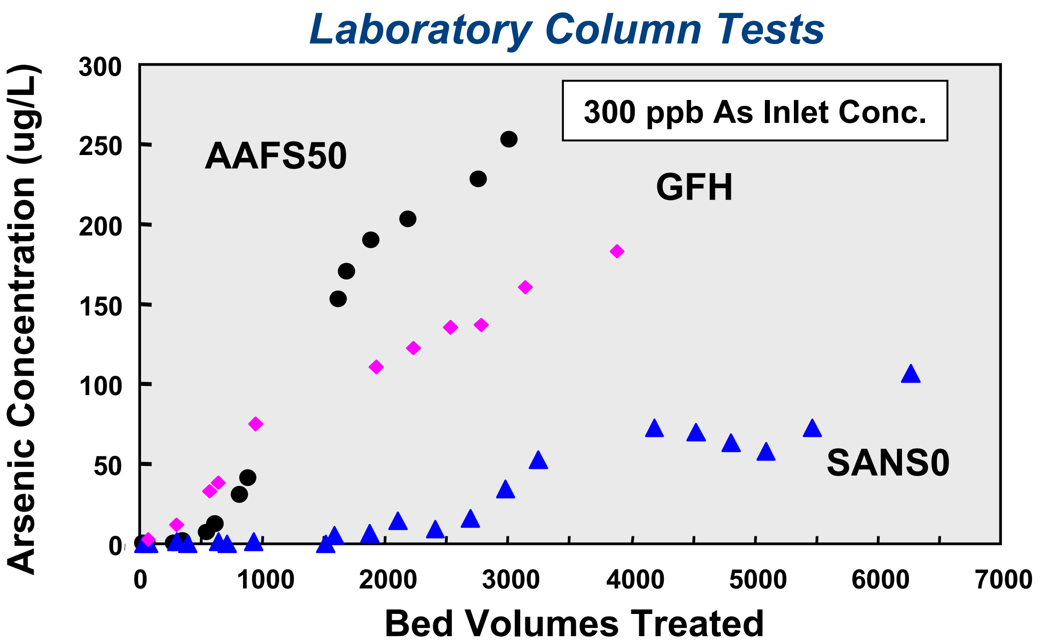
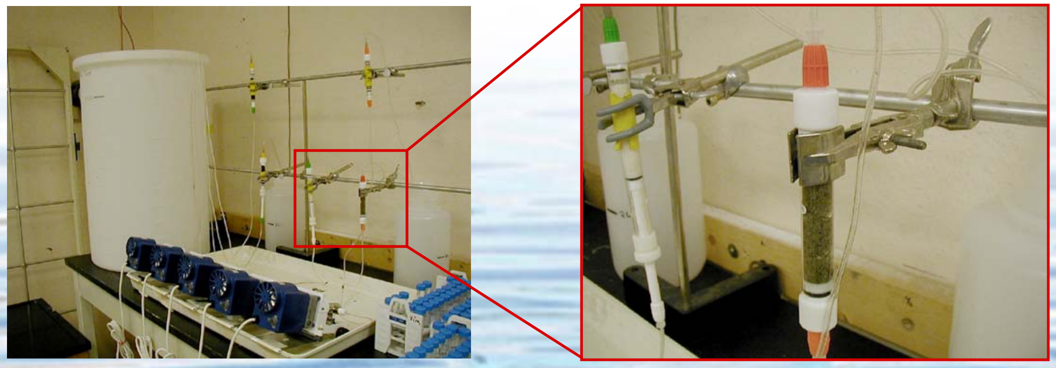
Sandia mixed metal oxide materials have approximately 10x the arsenic removal capacity of commercially available materials at laboratory scale



SANS Materials Pass Toxicity Characteristic Leaching Procedure (TCLP)



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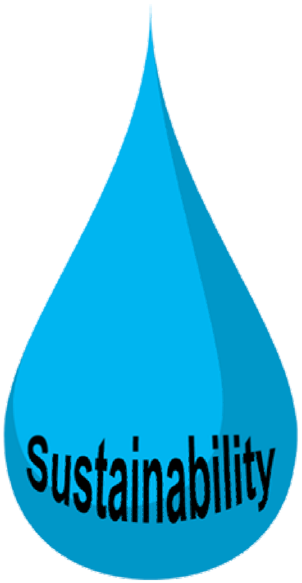
Water Treatment Technology:
Desalination



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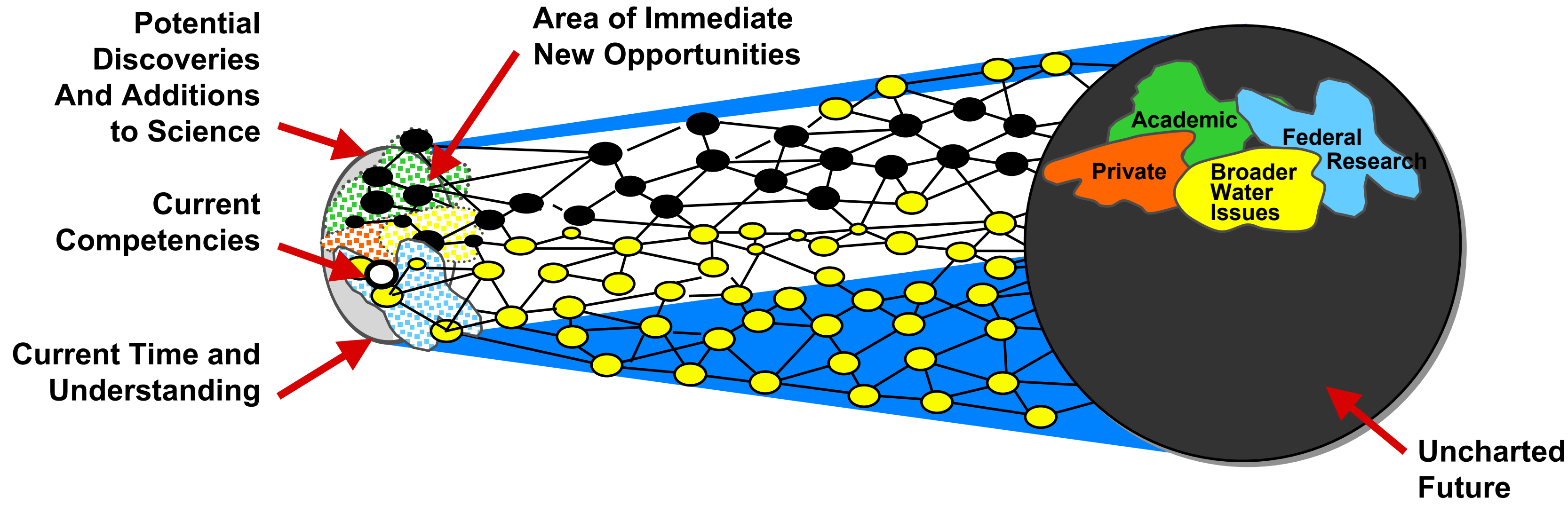
Sandia and the Bureau of Reclamation are developing a 20-year technology roadmap to drive desalination research to develop major cost saving technology breakthroughs



Unfolding Future Events and Technologies →

Executive Committee

Michael Gritzuk - Director Water Services, Phoenix
Anita Highsmith - Highsmith Environmental Consultants
Gary Wolff – Economist, Pacific Institute
William Blomquist - Political Scientist, Indiana University
David Furukawa - Desalination Consultant
Lisa Henthorne - Desalination Consultant
Peter Fox – Reuse, Arizona State University
Thomas Jennings - Desal R&D, International Programs, Bureau of Reclamation
Kevin Price - Desalination R&D Program Manager, Bureau of Reclamation
Thomas Hinkebein - Innovative Desal R&D, Brine Disposal, Sandia National Laboratories

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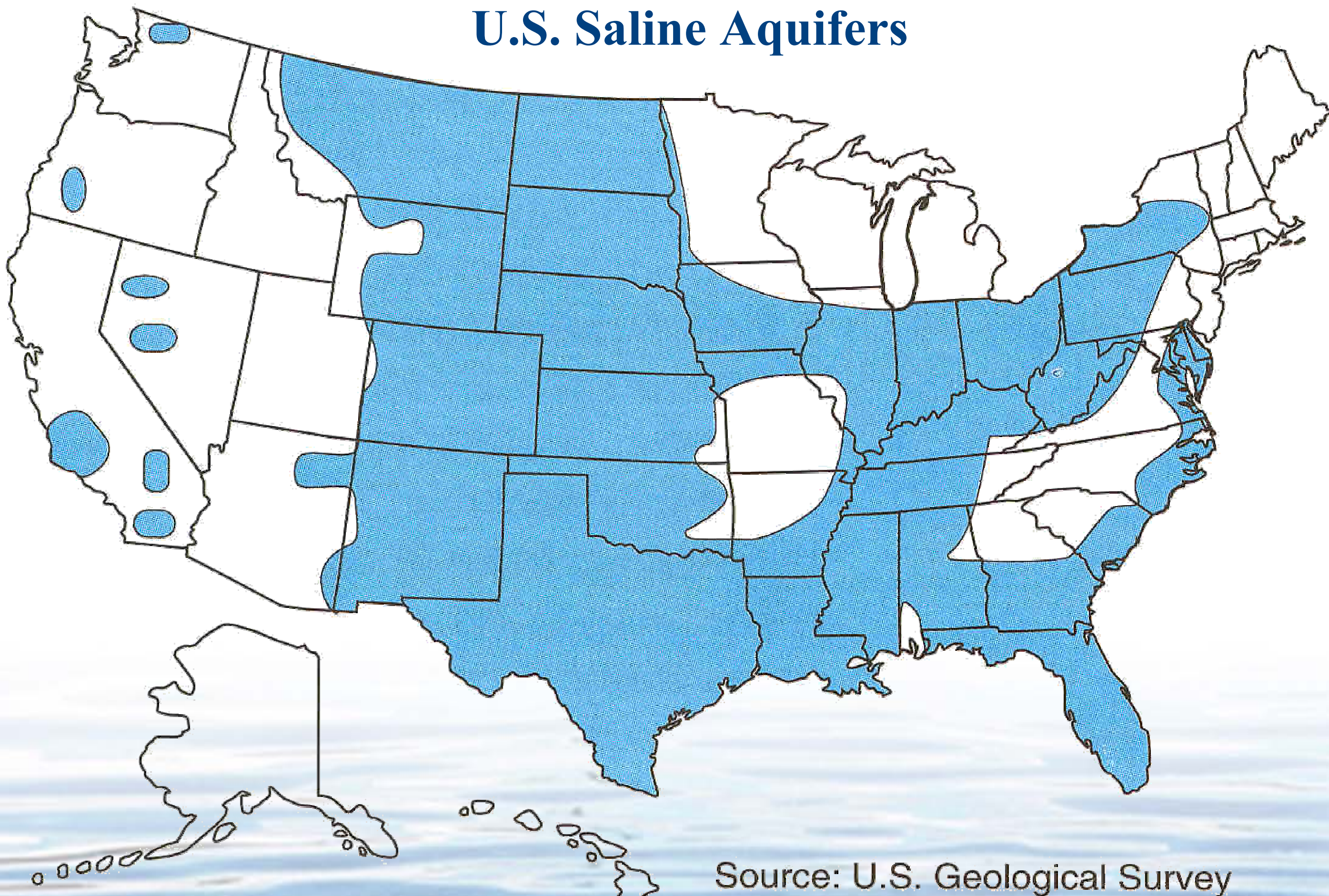
In addition to seawater, many countries have major inland, brackish water resources

U.S. Saline Aquifers



Source: U.S. Geological Survey

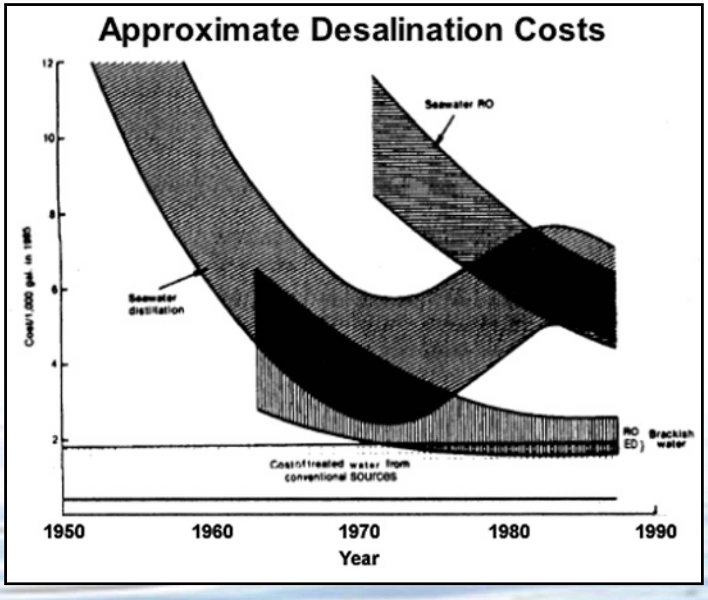
Driving vision for technology roadmap: U.S. water supply must be safe, sustainable, and affordable

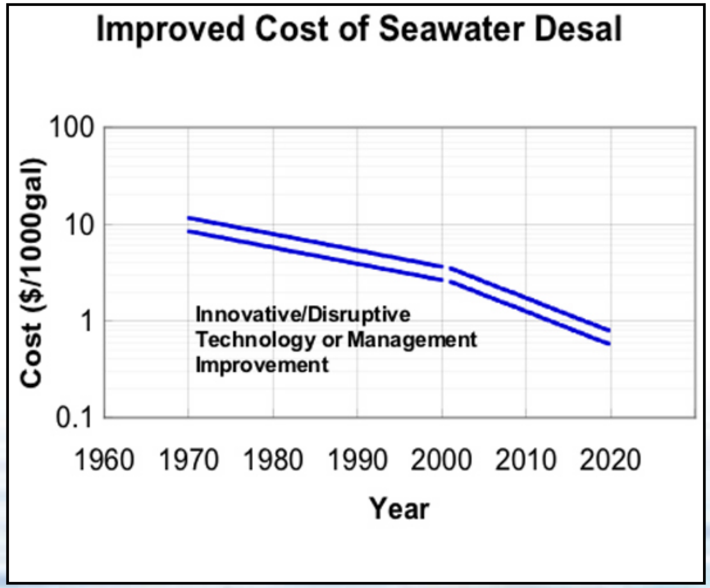
Today's reference costs:

- **$0.50 - $2.00 (municipal water in US)**
- **$0.01 - $0.18 (western irrigation)**
- **$0.05 - $0.08 (ground water costs)**

Key technology opportunities:

- **Lower energy salt removal processes**
- **By-product/concentrate disposal**
- **Alternative energy sources**





Roadmap will be complete in September, 2002

Category	Analysis Set	Scenario	2000		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010-2019				
			1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	1H	2H	2010-11	2012-13	2014-15	2016-17	2018-19
Vision 2020 - Needs	Safety	Security																									
		NaCl																									
		TDS																									
		Fecal coliform																									
		Disolved O2																									
		Phosporus																									
	Affordable	Consumer	$2.00 / Kgal																								
		Industry	$2.00 / Kgal														$1.65 / Kgal									$0.20 / Kgal	
		Agriculture																								$0.20 / Kgal	
	Sustainable	Aquifer drawdown																									
		Goal2																									
	Adequate	Delta capacity																									
		Per capita																									
Needs Spaces - Application Domains	Inland Rural	Opportunity Focus																									
		Result																									
	Inland Urban	Opportunity Focus																									
		Result																									
	Coastal	Opportunity Focus																									
		Result																									
	Reuse	Opportunity Focus																									
		Result																									
Core Competency Set	Intake/Pumps	Game-Changers													High efficiency pump												
	Membranes	Game-Changers															Non-fouling, high efficiency membrane										
	Thermal	Game-Changers																									
	Non-Traditional	Game-Changers												Proof of concept, laser purification													
	Concentrate Disp.	Game-Changers																						Commercial Reuse Application			
	Reuse-Recycling	Game-Changers																									
	Ancillary Systems	Game-Changers																									
	Tech Sharing	Game-Changers																									
	Decisions-Valuation	Game-Changers																									
	Education	Game-Changers																					Acceptance of on-site RO for potable				
Externalities	R&D	Funding Model	Federal budget - cost-sharing																								
		Funding Level	$3M / year					$5B / year								$10B / year							$20B / year				
	Institutional Roles	DOE	Facilitation						Desalination research																		
		Reclamation	Leadership role																								
		University	Funded Research																								
Issues & Trends	Population	Inland Rural																									
		Inland Urban																									
		Coastal																									
	Environment	Inland Rural																									
		Inland Urban																									
		Coastal																									
	Regulations	Inland Rural																									
		Inland Urban																									
		Coastal																									
					Committed				Limited Commitment				Uncommitted, but in LRP				Uncommitted, but not in LRP				TBD, N/A or Blue Sky						

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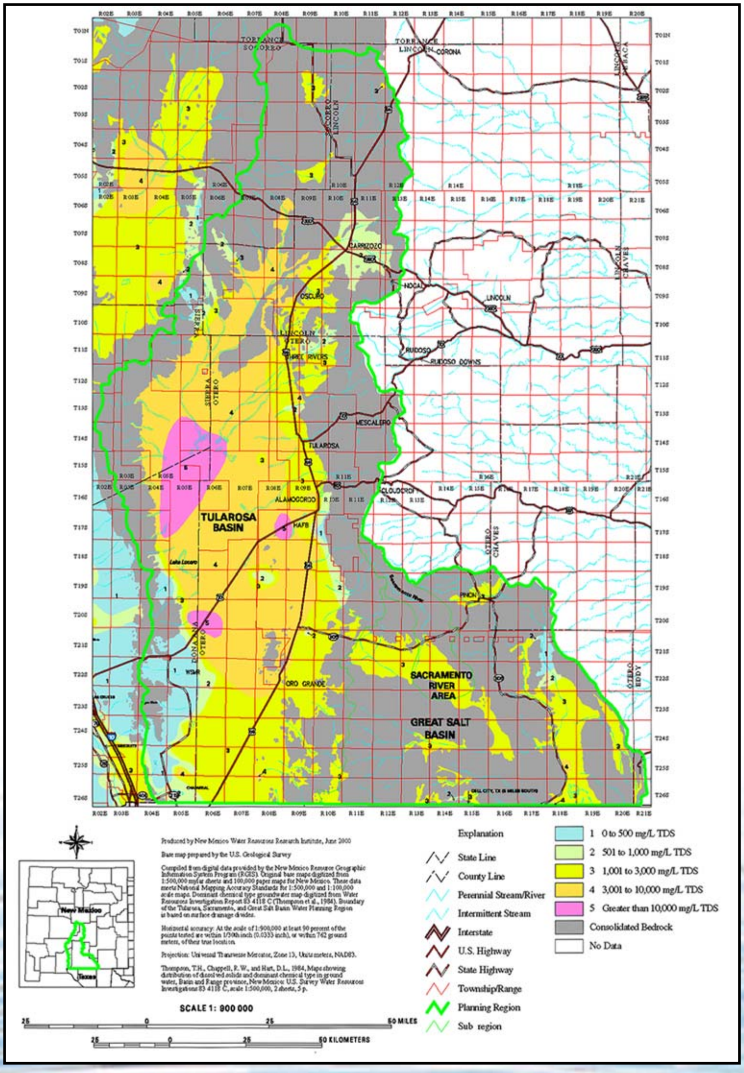
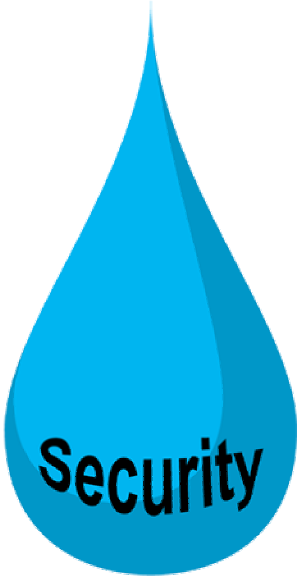
Sandia and the Bureau of Reclamation are also developing a field-scale desalination test facility in the Tularosa Basin in southern New Mexico



Tularosa test site criteria:

- **Access to solar, wind, and geothermal energy sources**
- **Access to large quantity of high- permeability, shallow saline groundwater**
- **Wide range of water quality, water chemistries, and brine concentrations over short distances**
- **Many brine disposal options**

Water Infrastructure Risk Assessment



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Sandia is building on a broad experience base in physical security to develop a rigorous vulnerability assessment methodology for water

Power Grid

Hydroelectric Dams

Nuclear Weapons

Nuclear Plants

Extensive experience and expertise in vulnerability assessments of critical facilities.

System-scale, risk-based vulnerability assessment of municipal water systems

WATERWORKS		
Facility:		
Date:		Recorded By:
Functional Area: Water Treatment		
Operational Features: *Physical Security*	**Reviewed** Y/N/NA	**Photo** Y/N
Boundary		
Fence (height and construction)		
Vehicle barriers		
Entrances: Personnel/Vehicle		
Entrance construction		
Entrance locks		
Entrance barriers		
Distance between boundary and building		
Building construction		
Entrance (doors, windows, vents, skylights) construction		
Entrance locks		
Entrance barriers		
Distance between entrance and critical asset		
Critical Asset enclosure construction		
Critical asset enclosure entrance construction		
Enclosure locks		
Enclosure barriers		
Sensors (helicopter, fence, intrusion, door/gate position, penetration, motion)		
Detection by personnel		
ID checks		
Contraband detection (persons, packages, vehicles)		
Assessment by cameras or personnel		
Tamper indicating measures		
Communication lines		
Alarm Display and Control		
Alarm Destination		

Comprehensive Analysis

Computer Simulation

Undesired Event	Measure of Consequence	High	Medium	Low
Loss of surface water	Economic loss	>$millions	$500K	<$500K
	Deaths	>5	<5	0
Contamination of water supply	Economic loss	>$millions	$500K	<$500K
	Illnesses	>100	<100	<5
	Deaths	>5	<5	0
Loss of distribution system	Economic loss	>$millions	$500K	<$500K
	Loss of public confidence	Depends on extent and duration	Depends on extent and duration	Depends on extent and duration

Security Risk Assessment Process

SCADA systems play an increasingly central role in the management and control of major water systems

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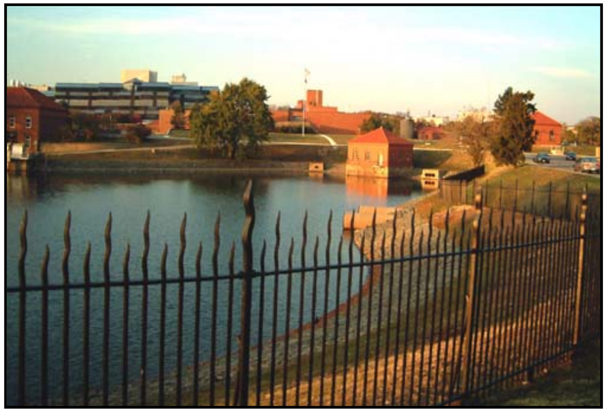
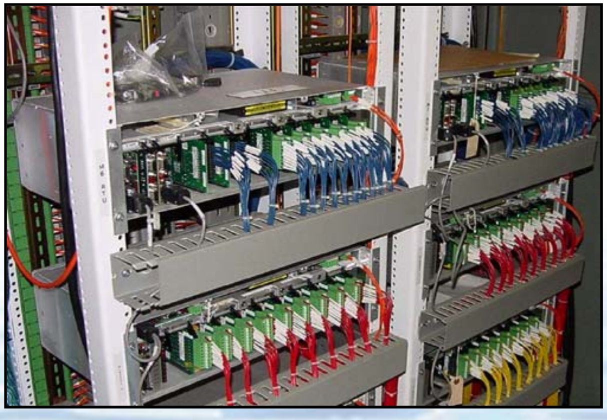
Water infrastructure vulnerability assessment activities have been greatly accelerated since 9/11/01

Vulnerability assessments of Major U.S. metropolitan water systems



Satellite network distributed training on security assessment for water utilities



Ongoing development of "train the assessor" training course for spring 2002

Hands-on vulnerability assessment training workshops in major cities across the U.S.

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Water infrastructure protection strategies laid out in November 14, 2001 congressional testimony

Near-Term *(assess water system vulnerabilities)*
- vulnerability assessments; training
- threat definition
- short-term risk reduction
- information protection issues
- complete methodology for waste water

Intermediate-Term *(protect water systems)*
- real-time, early warning monitoring systems
- physical system improvements
- SCADA system improvements
- technologies for management of compromised systems

Long-Term *(reconfigure water systems)*
- alternative system designs that reduce consequences
- advanced treatment technologies
- security driven design standards
- education of future system designers

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Highest priority challenges for water infrastructure security

- **Simultaneously meet the extreme near-term demand for vulnerability assessments, execute highest priority near-term follow up, and initiate longer-term, more robust strategies**
- **Develop a more comprehensive understanding of threats to water systems and translate this information to useful design basis threats**
- **Develop effective real-time monitoring systems and associated security management strategies for water distribution systems**
- **Identify and develop strategies and technologies for management of compromised systems**

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Real-Time Monitoring

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Emerging water sensor technologies enable real-time monitoring and real-time management, a key strategy in multiple water arenas

Security

Water Infrastructure Attack Protective Monitoring

- Early warning river/source monitoring
- Treatment system integrity
- Distribution system integrity

Safety

Water Quality Monitoring

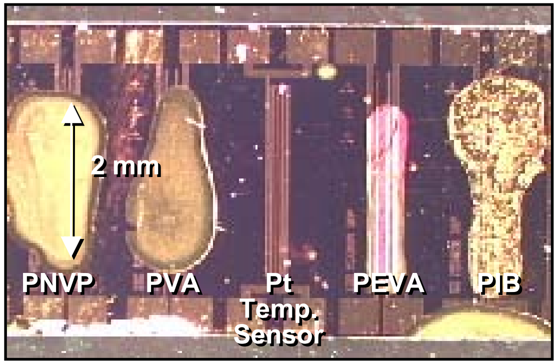
- Inflow - efficient monitoring of regulated contaminants in source water
- Outflow - efficient monitoring of regulated contaminants in treated water
- Treatment process optimization

Sustainability

Quantifying and Managing Water Sources

- Comprehensive source water quantification
- Real-time management of water flow/distribution
- Transparent verification of treaty/agreement allocations

Chemiresistor sensors will provide real-time, in situ monitoring of volatile organic compounds



Chemiresistor Array
(4 Different Polymer Films)

- **Continuous in situ monitoring of volatile organic compounds (toxic chemicals, explosives, etc.)**
  - **Polymer film with conductive particles forms chemically sensitive resistor**
  - **Extremely small, low-power system with no pumps or valves**
  - **Sensor array can provide analytic discrimination**

Waterproof sensor package for monitoring well or cone penetrometer

Field testing and commercialization are presently under way

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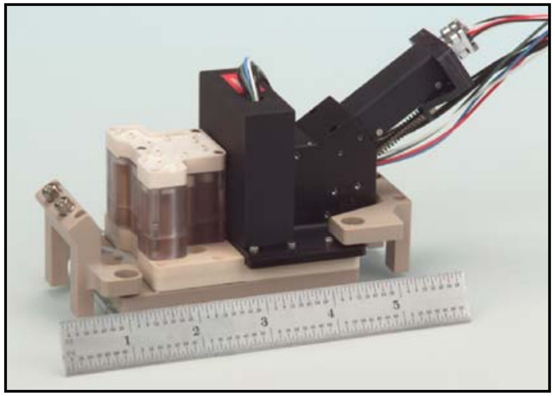
Sandia's μChemLab technologies are being tested to meet major needs in real-time water monitoring

- Biotoxins
  - Primary application in water security monitoring
  - Separation/detection technology successfully demonstrated
- Regulated contaminants (organics and metals)
  - Primary application in water safety/quality monitoring and process optimization
  - Have started work on translating analytic methods from literature to μChemLab
- Microbes/viruses
  - Application to both water security and safety/quality
  - Development of front end processing of samples is under way



Liquid μChemLab working prototype

Gas μChemLab field prototype

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International Cooperative Monitoring: Cooperative problem-solving and management of shared water resources

Today

A Vision for the Future

Technology and Tools

Today:
- sample collection
- laboratory analysis
- basic decision models

Sensors, Monitoring, Modeling, Data Analysis
- real-time data collection
- In situ data analysis
- detailed watershed modeling
- real-time remote monitoring

Decision Analysis
- macroscopic modeling
- management scenarios

Cooperative Activities

Today:
- confidence building through joint data collection
- Small-scale scientific collaborations
- initial efforts to model key watersheds

A Vision for the Future:
- shared scientific understanding of critical transboundary watersheds
- implementation of "active" watershed monitoring and analysis systems
- cooperative regional management and decision-making

Key Regions: Middle East, India/Pakistan, China, NE Asia, Central Asia, Caucasus, US/Mexico

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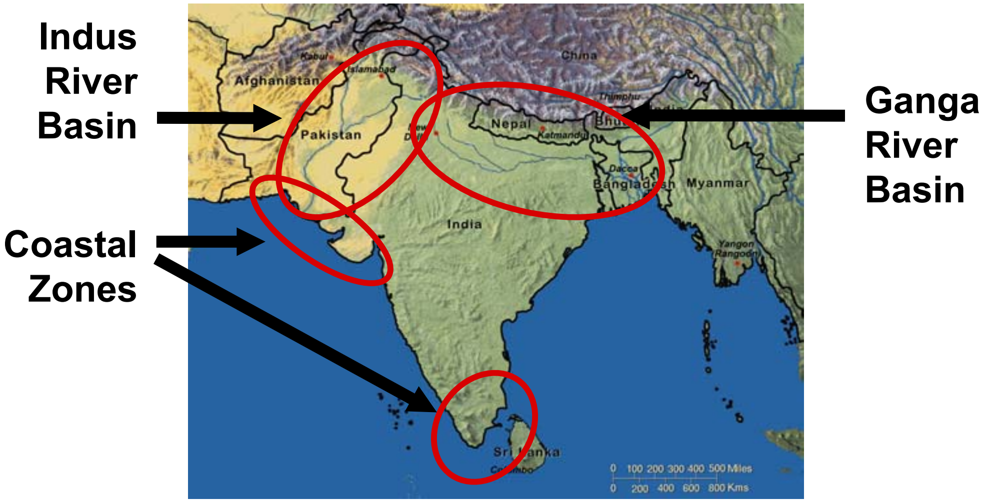
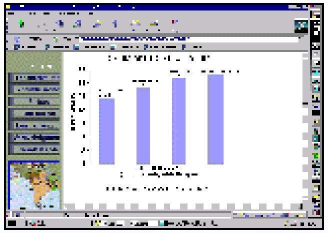
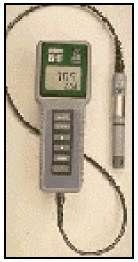
South Asia transboundary water quality monitoring

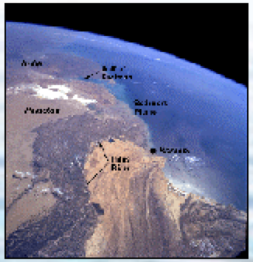
GOAL: Assess water quality throughout South Asia and promote transboundary watershed analysis and cooperation

- **Data collected by 6 partners in 5 countries and shared on a dedicated web site since 1999**
  - India, Pakistan, Nepal, Bangladesh and Sri Lanka
  - Additional partners, parameters and analysis beginning in 2001
- **Sponsors: DOE, USAID and U.S. State Department Office of Environmental Affairs**









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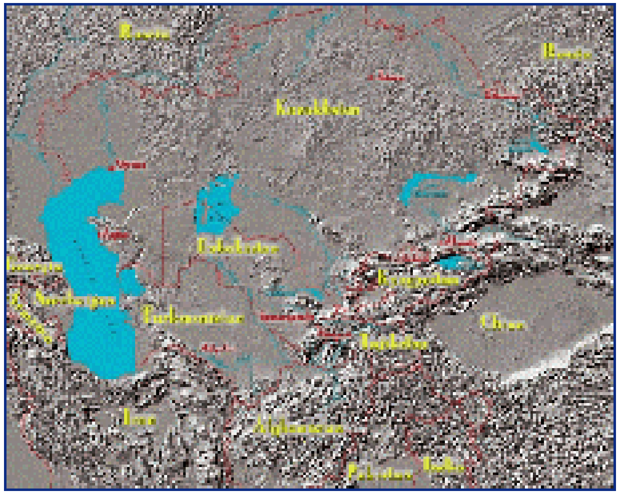
Transboundary river monitoring in Central Asia: The NAVRUZ Experiment

GOAL: Investigate existence of waterborne radiation to strengthen nonproliferation and build regional confidence and cooperation

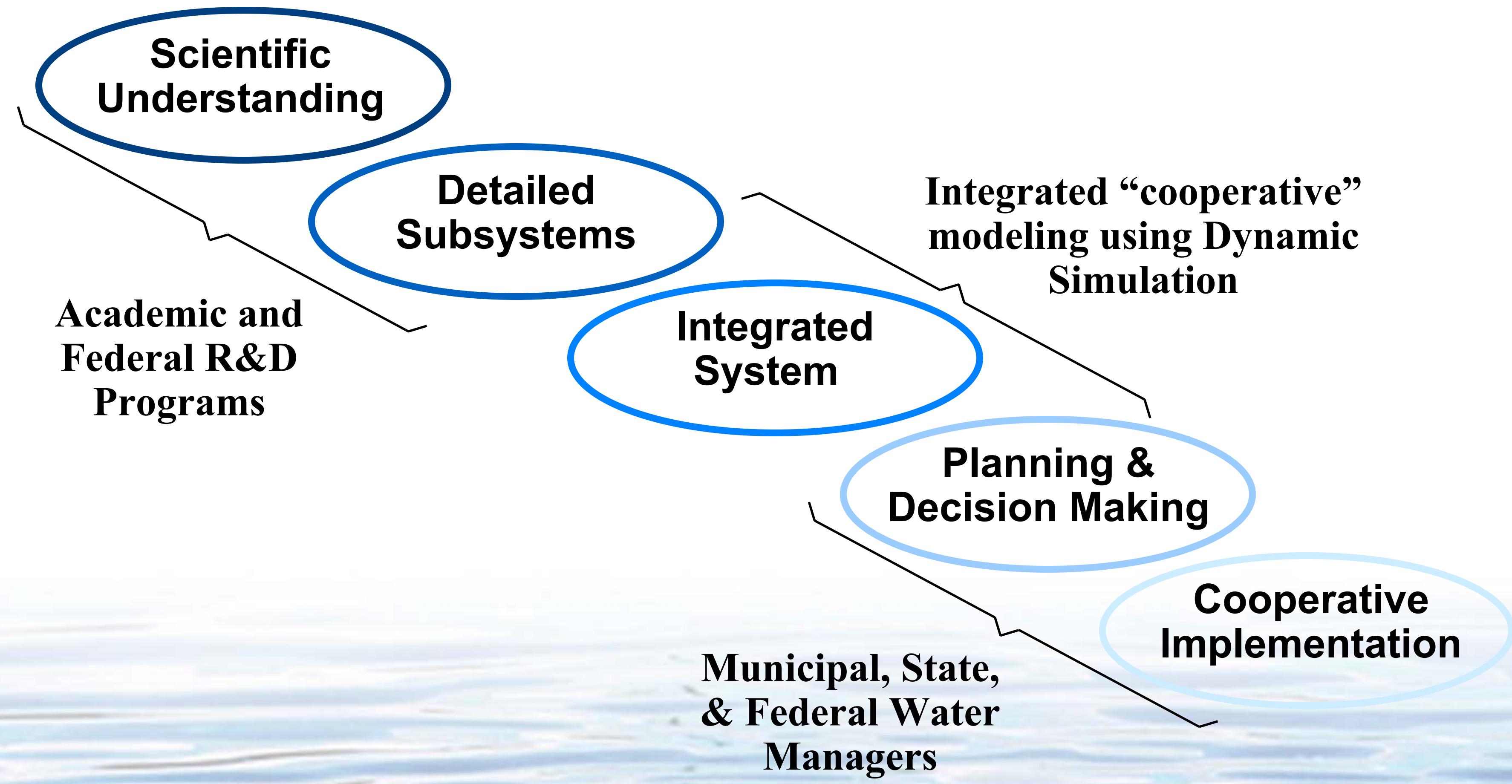
- Monitoring along Syr Darya, Amu Darya, and major tributaries in Central Asia
- Partners include scientists and technical experts from Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan
- Sample water, vegetation, sediment, and adjacent soil
- Analyze for radionuclides and basic water quality parameters
- Share data via the CMC Internet site



Participants in The Navruz Experiment during sample collection training.

Multi-Stakeholder Decision Modeling

Integrated "cooperative" modeling fills the major gap between detailed research/subsystem models and policy/decision making people and process



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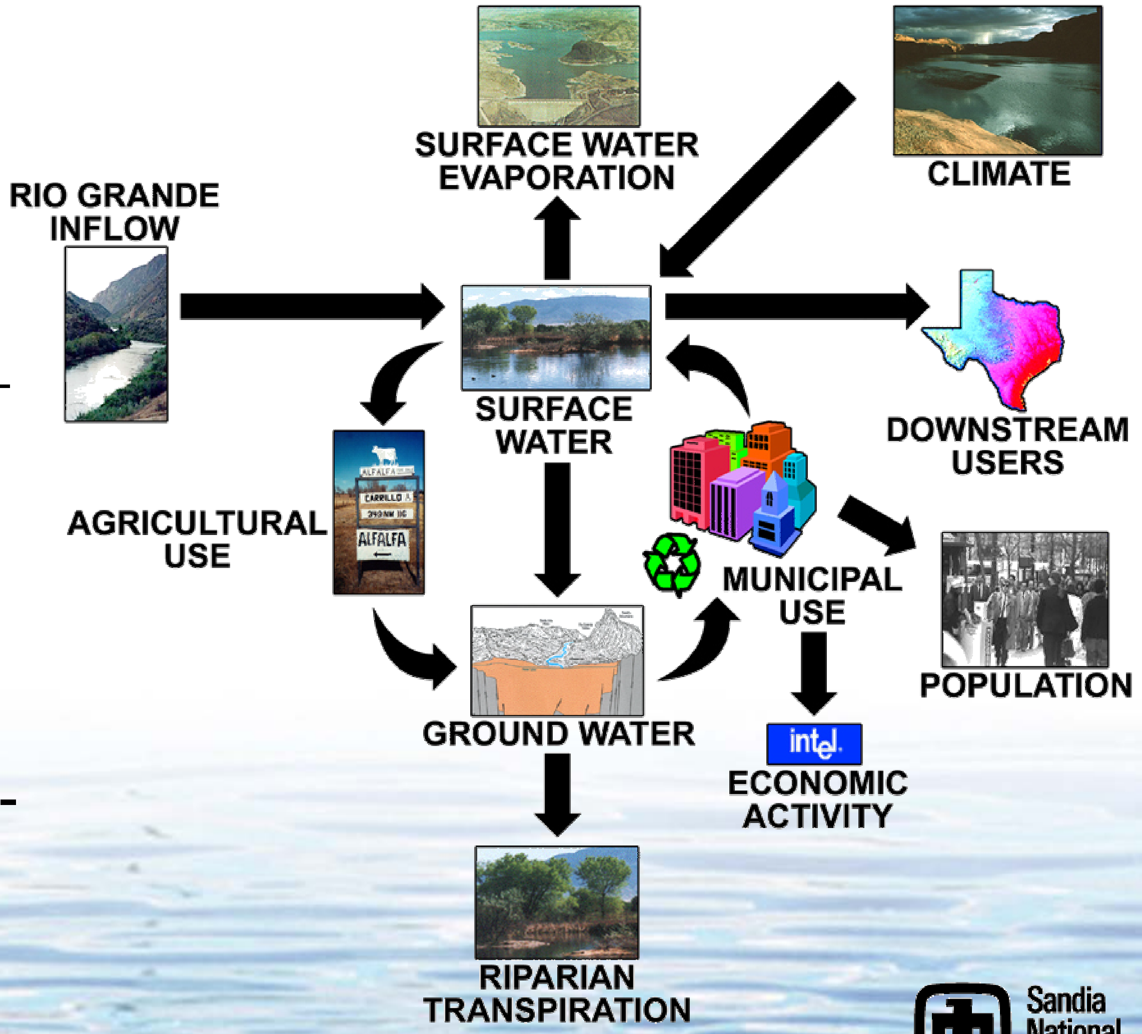
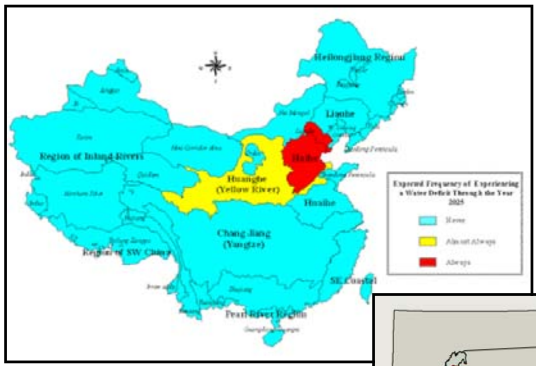
Dynamic simulation tools provide the software platform for direct stakeholder engagement in building system-level decision models

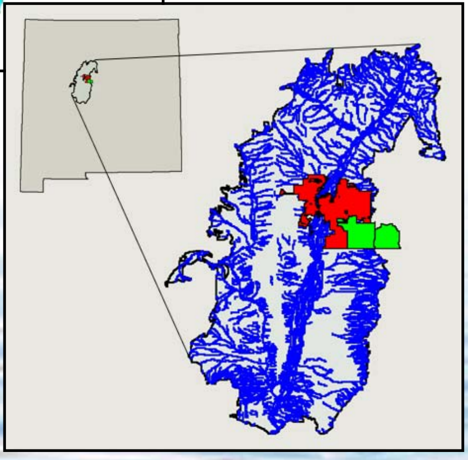
- Addresses all resource allocations
- Holistic
- Implement models on commercial software
- Accessible to the public – conceptually and direct manipulation
- Accommodates uncertainty for decision makers
- Easily modified for what-if decision making

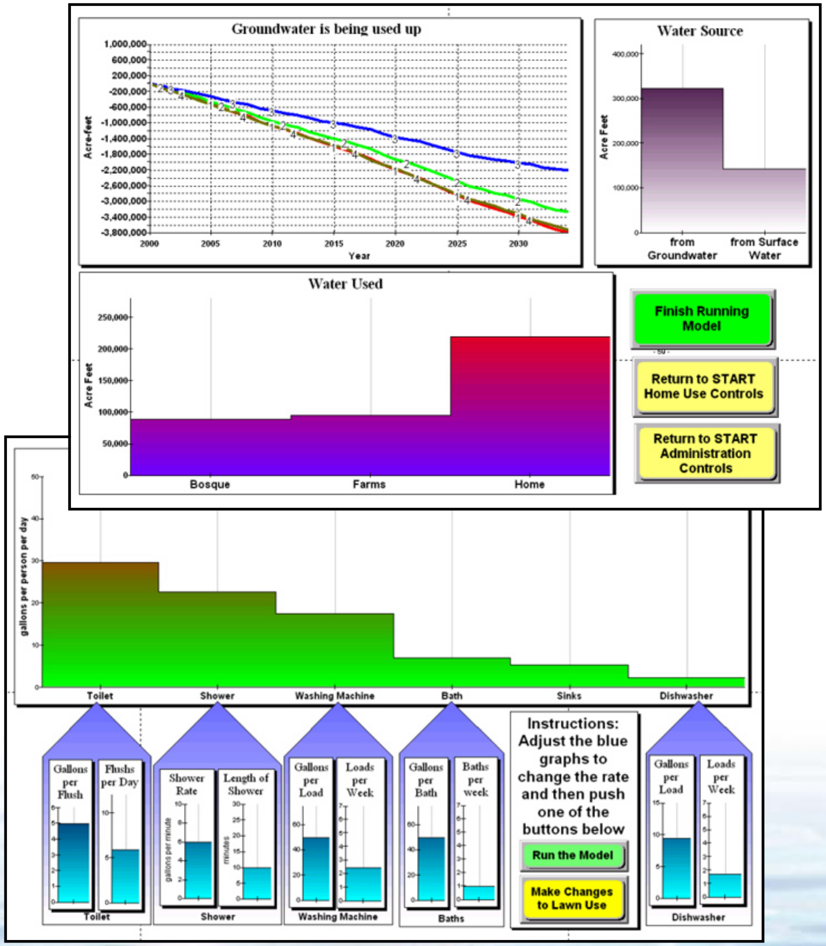


Dynamic simulation models have been built at a variety of basin scales and hydrologic system types

- China water and agriculture
- Middle Rio Grande Basin
- Estancia Basin

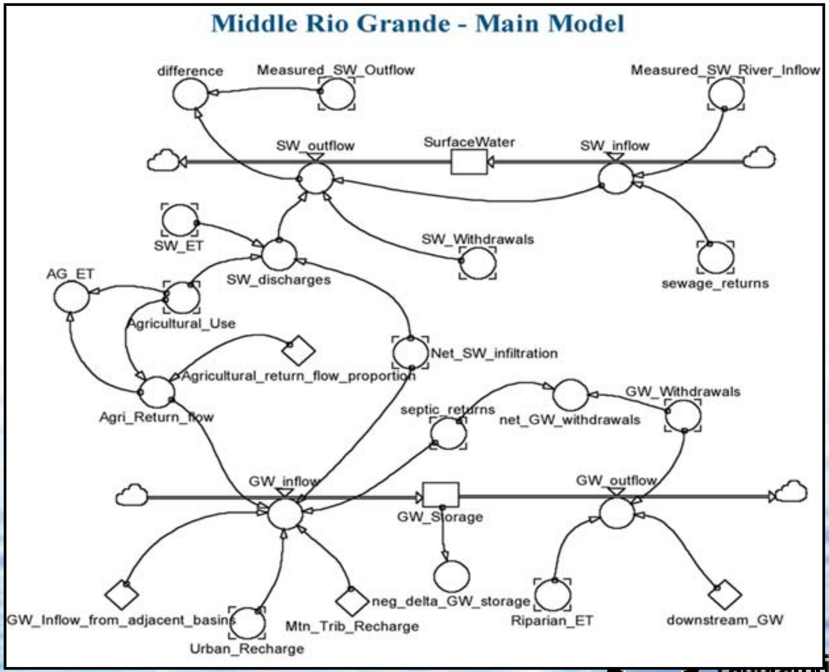






Middle Rio Grande Basin model is being created through a partnership of UNM Utton Law Center and Water Assembly and Council of Governments

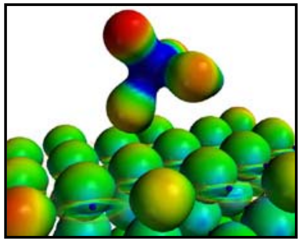
- SNL partners with UNM Utton Center, MRGCOG administrators, MRGWA members
- Cooperative model development with Assembly
- Goals:
  - Evaluate Alternative Management Strategies
  - Educate the Public about Issues
  - Assist in consensus building
- March Public Meetings
- Merge with State Engineers Balance Model
- Summer 2002 begin assessment alternatives



Laboratory Directed Research & Development (LDRD) Investments

Investments in water-related LDRD's are laying the groundwork in multiple water focus areas

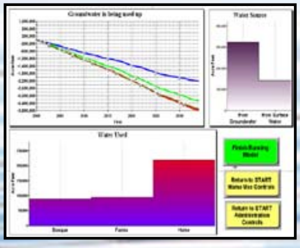
Started in FY01



Specific anion nanoengineered sorbents for water purification

Novel approaches for arsenic removal from water

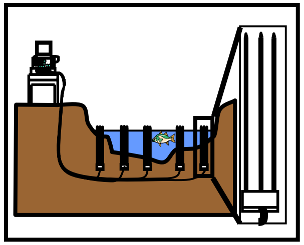
Micro-chemical sensors for volatile contaminants



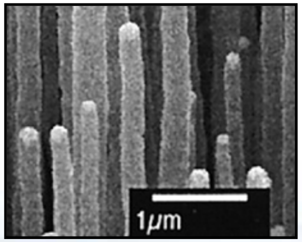
Innovative technologies for active water management

Started in FY02

Water desalination combined programs

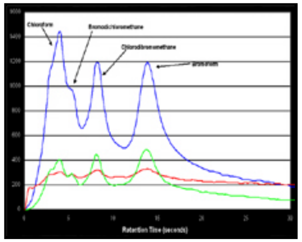


Remote, real-time monitoring of ephemeral streams

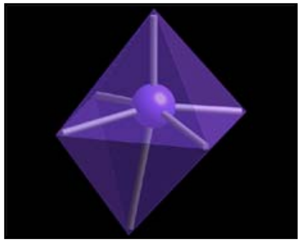


Nanoelectrode array sensors for regulated contaminants

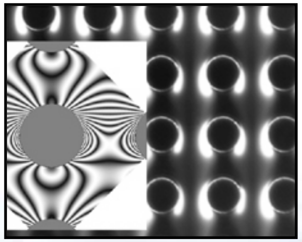
Starting in FY03



Real-time discriminatory sensors (for THMs)



Sequestration of pathogens on nanoengineered surfaces



Preconcentrator for live water-borne pathogens

Transport simulation of chem/bio/rad attack

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Sandia Water Initiative Web Site

www.sandia.gov/water